Assignment-3
Answer Key

Multiple Choice Questions -solutions

1.(b)

2. (a)

3. (a)

4. Rate of heat developed, $P = V^2/R$

For given V, $P \propto 1/R = A/\rho l = \pi r^2/\rho l$

Now, $P_1/P_2 = (r_1^2/r_2^2)(l_2/l_1)$

As per question, $l_2 = l_1/2$ and $r_2 = 2r_1$

$P_1/P_2 = (¼) \times (½) = ⅛$

$P_2 = 8P_1$ Answer: (a) Increased 8 times

5. Resistance after temperature increases by 500°C,

R_T = Voltage applied/Current = 220/2 = 110

Also, $R_T = R_0 (1 + \alpha\Delta T)$

$110 = 100 (1 + (\alpha \times 500))$

$\alpha = 10/(100 \times 500) = 2 \times 10^{-4}\ {}^0C^{-1}$

Answer: (b) $2 \times 10^{-4}\ °C^{-1}$

6. Resistance of a wire of length l and radius r is given by

$R = \rho l/A = (\rho l/A) \times (A/A)$

$R = (\rho V/A^2) = (\rho V/\pi^2 r^4)$ ($\because V = Al$)

i.e., $R \propto 1/r^4$

$R_1/R_2 = (r_2/r_1)^4$

Here, $R_1 = 100\ \Omega$, $r_1 = r$, $r_2 = r/2$

$R_2 = R_1(r_1/r_2)^4 = 16R_1 = 1600\ \Omega$

Answer: (d) 1600 Ω

7. Power of 15 bulbs of 40 W = 15 × 40 = 600 W

Power of 5 bulbs of 100 W = 5 × 100 = 500 W

Power of 5 fan of 80 W = 5 × 80 = 400 W

Power of 1 heater of 1 kW = 1000

Total power, P = 600 + 500 + 400 + 1000 = 2500 W

When these combination of bulbs, fans and heater are connected to 220 V mains, current in the main fuse of building is given by

$I = P/V = 2500/220 = 11.36\ A \approx 12\ A$

Answer: (d) 12 A

8. (b) increase by 0.2%

Resistance of wire $R = \rho l/A$… ..... (1)

On stretching, volume (V) remains constant.

So $V = Al$ or $A=V/l$

Therefore, $R = \rho l^2/V$ (Using (1))

Taking logarithm on both sides and differentiating we get,

$\Delta R/R = 2\Delta l/l$ (Since V and ρ are constants)

$(\Delta R/R)\% = (2\Delta l/l)\%$

Hence, when the wire is stretched by 0.1% its resistance will increase by 0.2%

Answer: (b) increase by 0.2%

9.(c) $P_2 > P_1 > P_3$

For $R_1 = 1$ ohm For $R_2 = 0.5\Omega$ $R_3 = 2\Omega$

As $P=V^2 / R$ and V=3 for each so Pa1/R

Thus, $P_2>P_1>P_3$.

10. (a) $I_R=I_G$

The reading of Galvanometer G is the same with switch S open or closed. This implies that closing or opening the switch does not affect the circuit. It means that no current flows through switch S. Hence, the given arrangement of resistors is a Balanced Wheatstone bridge. Hence we can remove switch S.

R and G will be in series. Hence current flows through resistor R is equal to the current flows through the galvanometer G. $\Rightarrow I_R=I_G$. Hence option (a) is correct.

11. (b)

$I = 6\text{-}3/3 = 3/3 = 1\ A$

$V_A - 6 + 1 - V_B = 0$

therefore $V_A - V_B = 5$

12 (c) 3E

I = 10 E / 10 r = E/ r

Current through three cells I x 3r = 3 E

13 (b) $R = R_0 (1 - BT)$

14. (a) number of charge carriers can change with temperature T.

(b) time interval between two successive collisions can depend on T

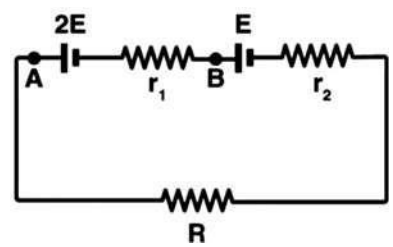
15. (a) The equivalent emf ε_{eq} of the two cells is between ε1 and ε2, i.e., $\varepsilon 1 < \varepsilon eq < \varepsilon 2$

16. (a) 2V, 0.5 Ω

17. c) -5A

18. (d) $(r_1/2) - r_2$

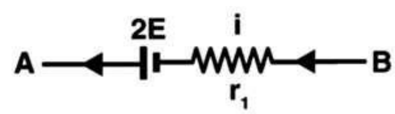
Solution



$I = \frac{3E}{R+r1+r2}$

If potential difference across terminals of first cell is zero

$V_A = V_B$



$2 E = i r_1 2E = \frac{3E}{R+r1+r2} r1$

$2R + 2r_1 + 2r_2 = 3r_1$

$R = (r_1/2) - r_2$

V.S.A

19. When area of the anode is decreased, the internal resistance of the cell increases. Lesser area of the anode decreases its tendency to attract oppositely charged ions

20. High resistivity and low temperature Coefficient of resistance

21. $ML^2A^{-1}T^{-3}$

22. In an alloy like nichrome (made of nickel and chromium), the free electron finds a disordered arrangement of nickel ions and chromium ions. Due to it, the electron is scattered by them randomly and very frequently. As a result of it, the value of relaxation time of electron decreases and hence resistivity increases because ρa1/τ.

23.(c)J = σ E

The current density at any point in ohmic resistor is in the direction of electric field at that point in space having non-uniform electric field. Charges released from rest may not move along electric line of force hence statement 1 is true while statement 2 is false

24. (d)R=R0(1+ αΔt) is valid only when the change in temperature is small and DR <<R0

Statement 1 is false and 2 is true

25. (c) statement 1 is true 2 is false

26. (c) statement 1 is true 2 is false

27. (c) statement 1 is true 2 is false

SOL Internal resistance is not characteristic property but depends upon the quantity and concentration of electrolyte and distance between the electrodes

28. (a) Both true 2 is explanation of 1

2 MARKS QUESTIONS SOLUTION

29.Ans. 1.6×10^6 A m^2; 1.25×10^4

$j = I/A = 1.6 \times 10^6\ Am^{-2}$

$v_d = j/ne = 1.25 \times 10^{-4}\ ms^{-1}$

30.a. $A = \frac{\pi D^2}{4} = 4.524 \times 10^{-6}\ m^2$

$j = I/A = 2.21 \times 10^6\ Am^{-2}$

b. $A = \frac{\pi D^2}{4} = 2.01 \times 10^{-6} m^2$

$v_d = I/neA = 3.7 \times 10^4\ ms^{-1}$

31.Ans. 1495.2 kg

$R = \frac{pl}{A}$

From which $A = 1.68 \times 10^{-5} m^2$

m = volume x density = A x l x density = 1495.2 kg

32. Ans: Nichrome Wire

$P = I^2 R$

P α R Heat produced is higher in Nichrome wire.

33. Solution $R_0 = 5\ \Omega$, $R_{100} = 5.23\ \Omega$ and $R_t = 5.795\ \Omega$

$$t = \frac{R_t - R_0}{R_{100} - R_0} \times 100, \qquad R_t = R_0\,(1+\alpha t)$$

$$= \frac{5.795-5}{5.23-5} \times 100$$

$$= \frac{0.795}{0.23} \times 100 = 345.65\ °\text{C}$$

34.Ans. 7.875 Ω

n = 100

D = 0.03 m

l = $n\pi D$ = 100 x π x 0.03m

$A = \pi r^2$

R=$\frac{\rho l}{A}$ = 7.875 Ω

35.v_d = (I/neA) Now, e = 1.6 × 10^{-19} C, A = 1.0 × $10^{-7}$$m^2$, I = 1.5 A. The density of conduction electrons, n is equal to the number of atoms per cubic metre (assuming one conduction electron per Cu atom as is reasonable from its valence electron count of one). A

cubic metre of copper has a massof 9.0 × 10^3 kg. Since 6.0 × 10^{23} copper atoms have a mass of 63.5 g,

$$n = \frac{6.0 \times 10^{23}}{63.5} \times 9.0 \times 10^6$$
$$= 8.5 \times 10^{28}\ \text{m}^{-3}$$

which gives

$$v_d = \frac{1.5}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.0 \times 10^{-7}}$$
$$= 1.1 \times 10^{-3}\ \text{m s}^{-1} = 1.1\ \text{mm s}^{-1}$$

(b) (i) At a temperature T, the thermal speed* of a copper atom of mass M is obtained from [< ($mv^2/2$) >3 kT/2] and is thus typically of the order of $\sqrt{kT/M}$, where k is the Boltzmann constant. For copper at 300 K, this is about 2 × 10^2 m/s. This figure indicates the random vibrational speeds of copper atoms in a conductor. Note that the drift speed of electrons is much smaller, about 10^{-5} times the typical thermal speed at ordinary temperatures. (ii) An electric field travelling along the conductor has a speed of an electromagnetic wave, namely equal to 3.0 × 10^8 m s^{-1}

The drift speed is, in comparison, extremely small; smaller by a factor of 10^{-11}

36. Ans. $V_A - V_B$ = – 8 volt.

37. Using KVL, ANS = -10 V.

38.

$$V = E + ir$$
$$= 2 + 0.15$$
$$= 2.15V$$

39. 2 / 5 Ampere

40. On applying Kirchhoff's current law on junction A, at junction A 2 + 3 = I + 4 so,

I = + 1A

41. In the circuit when an electron approaches a junction, in addition to the uniform E that faces it normally (which keep the drift velocity fixed), as drift velocity (vd) is directly proportional to Electric field (E). That's why there is accumulation of charges on the surface of wires at the junction.

These produce additional electric fields. These fields alter the direction of momentum. Thus, the motion of a charge across junction is not momentum conserving.

3 MARKS QUESTIONS SOLUTION

42. v_d = (I/neA) Now, e = 1.6×10^{-19} C, A = $1.0 \times 10^{-7} m^2$, I = 1.5 A.

The density of conduction electrons, n is equal to the number of atoms per cubic metre (assuming one conduction electron per Cu atom as is reasonable from its valence electron count of one). A cubic metre of copper has a mass of 9.0×10^3 kg. Since 6.0×10^{23} copper atoms have a mass of 63.5g,

$$n = \frac{6.0 \times 10^{23}}{63.5} \times 9.0 \times 10^6$$
$$= 8.5 \times 10^{28}\ m^{-3}$$

which gives

$$v_d = \frac{1.5}{8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.0 \times 10^{-7}}$$
$$= 1.1 \times 10^{-3}\ m\ s^{-1} = 1.1\ mm\ s^{-1}$$

(b) (i) At a temperature T, the thermal speed* of a copper atom of mass M is obtained from [< $(mv^2/2)$ >3 kT/2] and is thus typically of the order of $\sqrt{kT/M}$, where k is the Boltzmann constant. For copper at 300 K, this is about 2×10^2 m/s. This figure indicates the random vibrational speeds of copper atoms in a conductor. Note that the drift speed of electrons is much smaller, about 10^{-5} times the typical thermal speed at ordinary temperatures. (ii) An electric field travelling along the conductor has a speed of an electromagnetic wave, namely equal to $3.0 \times 10^8\ m\ s^{-1}$

The drift speed is, in comparison, extremely small; smaller by a factor of 10^{-11}

43. Length of aluminium = l1

Resistance of aluminium = R

Resistivity of aluminium, ρAI =ρ1= 2.63×10^{-8} Ωm

Relative density of aluminium, d1 =2.7

Area of cross-section of the aluminium wire =A1

Length of copper = l2

Resistance of copper = R2

Resistivity of copper, ρcu =ρ2=1.72×10^{-8} Ω m

Relative density of copper, d2 = 8.9

Area of cross-section of the copper wire =A2

Therefore,

$R_1=\rho_1 l_1/A_1$ and $R_2=\rho_2 l_2/A_2$

$\rho_1 l_1/A_1=\rho_2 l_2/A_2$

Given l1 = l2 $A_1/A_2=\rho_1/\rho_2 = 1.52$

Mass of aluminium, m1 = Volume x density= A1l1 x d1

Mass of copper = m2 = Volume x density= A2l2 x d2

$m_1/m_2 =(A_1 d_1 / A_2 d_2)$

$m_1/m_2 = (1.52) \times (2.7/8.9)= (1.52) \times (0.303)$, $m_1/m_2 = 0.46$

44. When the current through the element is very small, heating effects can be ignored and the temperature T1 of the element is the same as room temperature. When the toaster is connected to the supply, its initial current will be slightly higher than its steady value of 2.68 A. But due to heating effect of the current, the temperature will rise. This will cause an increase in resistance and a slight decrease in current. In a few seconds, a steady state will be reached when temperature will rise no further, and both the resistance of the element and the current drawn will achieve steady values. The resistance R2 at the steady temperature T2 is

R2= 230 V /2.68 A = 85.8 Ω

Using the relation $R_2 = R_1 [1 + \alpha (T_2 - T_1)]$ with $\alpha = 1.70 \times 10^{-4}$ °C^{-1},

we get T2 – T1 = 820 °C

that is, T2 = (820 + 27.0) °C = 847 °C

Thus, the steady temperature of the heating element (when heating effect due to the current equals heat loss to the surroundings) is 847 °C.

45. Ans.(a) $[I T^{-1}]$, [I] and [I T]

(b) 23 A

Here, $q = a t^2+bt+c$

(a) Dimensions of each factor on R.H.S. of the above relation are that of charge i.e. current x time or [IT].

$[a]=\frac{q}{t^2} = [IT^{-1}]$

$[b]=\frac{q}{t} = [I]$

[c] = [q] = [IT]

(b) Here, a = 3, b = 5 and c = 2

Now, I = dq/dt = 2at+b

I (at t = 3 s) =2x3x3+5= 23 A

46. From Kirchhoff's I law $I_3 = I_1 + I_2$ …(i)

Applying Kirchhoff's II law to loop PRSP

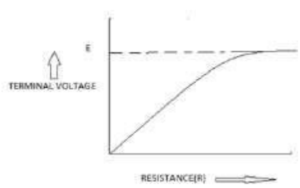
$- 20I_3 -200I_2 + 5 = 0$

$=> 40I_2 + 4I_3 =$ …(ii)

Applying Kirchhoff's II law to loop PRQP

$- 20I_3 - 60I_2 + 4 = 0$

$=> 15I_1 + 5I_3 = 1$



47. V = I R $= \frac{E}{r/R+1}$ V= EMF, when no current is drawn from the cell.

48. Ans. I) SERIES

$E_{eq} = E_1 + E_2 +E_3$ ——— $+E_n = nE$

$r_{eq} = r_1 + r_2 + r_3$ ——— $+r_n = nr$

E_{net} = 4 X 1.4 = 5.6 V

r_{eq}= 4X.8 = 3.2-ohm R =10-ohm R_{net} = 13.2 ohm

I = 5.6 /13.2 = I_{series} = 0.424A

FOR PARALLEL

$E_{eq} = E$

$(1/r_{eq}) = (1/r_1) + (1/r_2) + (1/r_3)$.......... $(1/r_n)$

$E_{parallel} = 1.4$ V

r_{eq}= .8 /4=.2 ohm R =10 ohm Rnet = 10.2 ohm

I = 1.4 /10.2 =$I_{parallel}$ = 0.137A

current through each cell is 0.03A

49. EMF = E $R_{net} = r + 2$

I = E / r + 2 = 0.5

0.5 X2 + 0.5 r = E ………… 1)

Similarly

0.25 X5 + 0.25 r = E ....2)

Solving

r = 1 ohm, E = 1.5 V

when short circuited, current = 1.5

50. In 1st loop

$-R+1+2=0$

$\Rightarrow R=3\Omega$

In 2nd loop

$-2R_1+2-2=0 \quad \Rightarrow R_1=0$

Now going from point, A to B via C.

$V_A+1-0=V_B \quad \Rightarrow V_B=1V$

5 MARKS QUESTIONS SOLUTION

51.(a) Each 'free' electron does accelerate, increasing its drift speed until it collides with a positive ion of the metal. It loses its drift speed after collision but starts to accelerate and increases its drift speed again only to suffer a collision again and so on. On the average, therefore, electrons acquire only a drift speed.

(b) Simple, because the electron number density is enormous, ~1029 m^{-3}.

(c) By no means. The drift velocity is superposed over the large random velocities of electrons.

(d) In the absence of electric field, the paths are straight lines; in the presence of electric field, the paths are, in general, curved

52.(a)1/17 A, 9/17 A, 8/17 A

(b)2.35 V

53. In loop ABCEA

$I_1+I_1=2$

$I_1=1A$

From loop ADCEA

$1.5I_2+ I_2=2$

$I_2=0.8A$

$V_A-V_B=1x1=1V$

$V_A-V_D=0.8x1.5=1.2V$

$V_B-V_D=1.2-1.0=0.2V$

54. From loop ABDA

$5I_1+10I_g-(I-I_1)15=0$

Put I=1A

$4I_1+2I_g=3$

For Loop BCDB

$10(I_1-I_g)-20(I-I_1+I_g)-10I_g=0$

Put I-1A

$3I_1-4I_g=2$

On solving

$I_g=1/22=0.0454A$

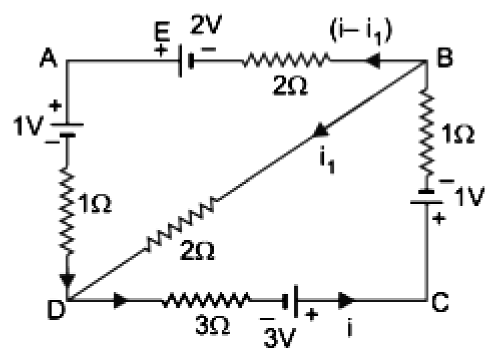
55. Applying Kirchhoff's second law to mesh BADB,

$-2(i - i_1) + 2 - 1 - 1. (i - i_1) + 2i_1 = 0$

$\Rightarrow 3i - 5i_1 = 1$ …(i)

Applying Kirchhoff's law to mesh DCBD,

$-3i + 3 - 1 - 1\times i - 2i_1 = 0$



⇒ $4i + 2i_1 = 2$

Or $2i + i_1 = 1$ …(ii)

Multiplying equation (ii) with

5, we get $10i + 5i_1 = 5$ …(iii)

Adding (i) and

(iii), we get $13i = 6$

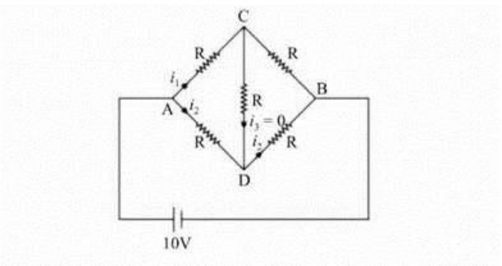
⇒ $i = 6/13$ A

From (ii), $i_1 = 1 - 2i = 1 - 12/13 =$

1/13 A Potential difference

between B and D is $V_B - V_D = i_1 \times$

$2 = 2/13$ V



56. R_{AB}= 2 Ohm

$I_{CD} = 0$

$I_{ACB} = V/2R = 10/4 = 2.5$ A

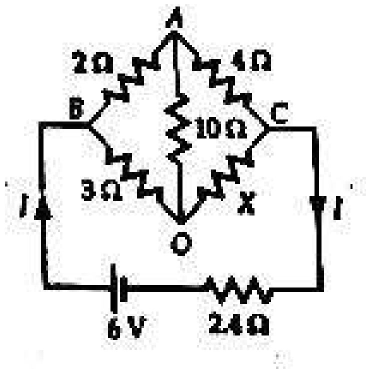
57. Using $\frac{P}{Q} = \frac{R}{X}$

$X = \frac{SU}{S+U}$

Put X=2, S=3, Find U =

unknown U=3 ohm

I = V /3



58. No current flows through section AO, So Wheatstone Bridge is balanced

2/4 =3/X

X= 6

ohm

R_{BAC} =

6 Ohm

R_{BOC} = 9 ohm

$R = \frac{6*9}{6+9} = 3.6$

Total resistance =

3.6+2.4= 6 I=6/6=1A